Journal of Southeast University (English Edition) Vol. 35, No. 1, pp. 1 - 7 Mar. 2019 ISSN 1003—7985

Admission control based on beamforming and interference alignment for D2D communication underlaying cellular networks

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Abstract: An admission control algorithm based on beamforming and interference alignment for device-to-device (D2D) communication underlaying cellular networks is proposed. First, some portion of D2D pairs that are the farthest away from the base station (BS) is selected to perform joint zero-forcing beamforming together with the cellular user equipments (UEs) and is admitted to the cellular network. The interference of the BS transmitting signal to the cellular UEs and the portion of D2D pair is eliminated completely at the same time. Secondly, based on the idea of interference alignment, the definition of channel parallelism is given. The channel parallelism of the remaining D2D pairs which are not involved in joint zero-forcing beamforming is computed by using the channel state information from the BS to the D2D devices. The higher the channel parallelism, the less interference the D2D pair suffers from the BS. Finally, in a descending order of channel parallelism, the remaining D2D pairs are reviewed in succession to determine admission to the cellular network. The algorithm stops when the admission of a D2D pair decreases the system sum rate. Simulation results show that the proposed algorithm can effectively reduce the interference of the BS transmitting signal for D2D pairs and significantly improve system capacity. Furthermore, D2D communication is more applicable to short-range links.

Key words: device-to-device (D2D) communication; cellular network; admission control; beamforming; interference alignment

DOI: 10.3969/j.issn.1003 - 7985.2019.01.001

I n recent years, the popularity of smartphones has grown rapidly all over the world. Multimedia services such as mobile computing and streaming media are also developing rapidly. The volume of mobile data transmitted on cellular networks is predicted to have a thousand-fold increase by 2025[1]. Existing cellular network technology will not be able to meet this huge data demand due to the physical limits on the available radio frequency spectrum. Researchers are actively seeking solutions to this problem. The fifth generation (5G) is essentially a combination of various advanced technologies that are intended to meet a wide range of user needs in the future. Device-to-device (D2D) communication has drawn wide attention as one of the key components of 5G technology[2].

In cellular networks, D2D communication refers to direct communication between two proximal cellular user equipments (UEs) under the control of the base station (BS). No data is transferred through the BS or the core network, which can greatly reduce the traffic load of the BS and facilitate network deployment. In cellular networks, D2D communication is classified as non-transparent transmission. Data can be transmitted using the licensed in-band spectrum or the unlicensed out-of-band spectrum. The distance between the transmitter and the receiver of a D2D pair is very short, so the transmission power can be much lower than that needed for the cellular network communications, which reduces the necessary amount of system energy. In addition, D2D and cellular network communications can share the same spectrum resources, which offers great improvement in spectral efficiency. D2D communication also offers the advantages of reducing data latency and improving user fairness.

For D2D communication underlaying cellular networks, the cellular UEs and D2D pairs will share the same frequency spectrum, so interference between the cellular networks and the D2D transmissions is a serious problem. Through effective interference management, resource allocation, mode selection, and multiple-input multiple-output (MIMO) technology, the spectral efficiency can be improved[3-4]. Interference management algorithms can also be used to improve system capacity and they have attracted much attention[5-6]. A scheme for reusing cellular uplink resources for D2D communication

Received 2018-09-24, **Revised** 2018-12-25.

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Foundation items: The National Natural Science Foundation of China (No. 61771132, 61471115), the Natural Science Foundation of the Higher Education Institutions of Jiangsu Province (No. 16KJB510011), the Science and Technology Joint Research and Innovation Foundation of Jiangsu Province (No. BY2016076-13), the Research Fund of National Mobile Communications Research Laboratory, Southeast University (No. 2018A02), the Research Foundation of Jinling Institute of Technology for Advanced Talents (No. 40620044).

Citation: Wang Gang, Li Yongmei, Meng Chao, et al. Admission control based on beamforming and interference alignment for D2D communication underlaying cellular networks[J]. Journal of Southeast University (English Edition), 2019, 35(1): 1 - 7. DOI: 10.3969/j.issn.1003 - 7985.2019.01.001.

was proposed[7]. Since the D2D pairs multiplexed the uplink frequency spectrum, uplink transmission interference might occur at the BS. By monitoring the power of the received downlink control signal, the path loss between the D2D transmitters and the BS can be estimated. Therefore, D2D transmitters kept their transmission power below a predefined threshold to avoid significant interference with the cellular networks. An innovative interference avoidance method to maximize the overall system throughput was proposed[8], in which D2D communication reused the uplink spectrum resources of the cellular networks. A scheduling algorithm based on graphs for D2D communication overlaying cellular networks was presented[9]. A novel resource allocation scheme based on auctions in the downlink was proposed[10], and it improved the sum rate performance of the system. However, none of the above studies makes full use of MIMO technology for interference cancelation.

MIMO is an effective technique to reduce interference and to improve the system's spectrum efficiency, and it can also be used in D2D communication scenarios. A heuristic precoding algorithm, in which the channels from the BS to the cellular UEs lie in the null space of the interference channels from the BS to the D2D pairs, was presented[11]. A non-cooperative game strategy with joint channel allocation, power control, and the precoding of D2D users was proposed[12], and the sum rate maximization problem that included cellular users and D2D pairs was formulated. Using physical layer network coding and mapping, a joint precoding and decoding scheme was proposed to eliminate interference and improve system performance in MIMO D2D communication[13]. A D2D association algorithm that considered three types of precoding methods was proposed for D2D communication underlaying cellular networks[14]. Among these proposals, precoding is usually applied to prevent interference between cellular UEs or between the D2D pairs, whereas joint precoding is rarely considered. On the other hand, the interference alignment method is usually not considered for use in conjunction with the precoding method. The present work combines these techniques in a unique way.

In this paper, a cellular network with multiple cellular UEs and D2D pairs is considered, and the BS is equipped with multiple transmitting antennas. First, by using the channel state information (CSI) from the BS to the cellular UEs and to the receivers of some of the D2D pairs, joint zero-forcing beamforming is applied at the BS. The channels from the BS to the first portion of the D2D pairs lie in the null space of the precoding matrix of the cellular UEs, so that the transmission signals from the BS have no interference on this portion of the D2D pairs. Next, channel parallelisms between the channels from the BS to the rest of the D2D pairs and the channels from the BS to the above-mentioned portion of D2D pairs are calculated, and they are used to align these two portions of the interference channels. The rest of the D2D pairs are checked one by one in a descending order of the channel parallelisms, where higher parallelism means lower BS interference. If the sum rate of all the cellular UEs and D2D pairs increases when a D2D pair is admitted to the system, its admission is confirmed; otherwise, admission is denied, and the algorithm terminates. Simulation results show that the proposed D2D admission control algorithm performs better than the existing algorithms.

1 System Model and Problem Formulation

1.1 System model

As shown in Fig. 1, a single cell multi-user downlink cellular network with multiple D2D pairs underlaying communications is considered. The BS has N_t transmitting antennas, and each of the cellular UEs and D2D users has a single antenna. The sets of the cellular UEs and D2D pairs are defined as $A=\{1,2,\cdots,K\}$ $(K<N_t)$ and $B=\{1,2,\cdots,D\}$, respectively. The transmitter and the receiver of the d-th D2D pair $D2D_d$ are DT_d and DR_d, respectively.

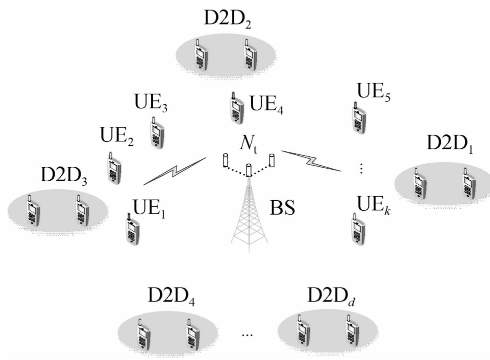

Fig. 1 D2D communication underlaying cellular network

Let the signal vector transmitted by the BS to K cellular UEs be

$$\boldsymbol{x}=[x_1,x_2,\cdots,x_K]^{\mathrm{T}} \tag{1}$$

where x_k is the signal for the k-th cellular UE with $E\{|x_k|^2\}=1$, $k\in A$. y_d is the transmission signal of DT_d, with $E\{|y_d|^2\}=1$, $d\in B$. The precoding matrix for all cellular UEs $\boldsymbol{W}\in\mathbf{C}^{N_t\times K}$ is defined as

$$\boldsymbol{W}=[\boldsymbol{w}_1,\boldsymbol{w}_2,\cdots,\boldsymbol{w}_K] \tag{2}$$

where $\boldsymbol{w}_k\in\mathbf{C}^{N_t\times 1}$ is the precoding vector for the k-th cellular UE.

Meanwhile, the channel gain vector from the BS to the k-th cellular UE and to DR_d are denoted as $\boldsymbol{h}_{B,k}\in\mathbf{C}^{N_t\times 1}$ and $\boldsymbol{f}_{B,d}\in\mathbf{C}^{N_t\times 1}$, respectively, and they are all available at the BS. The channel gains from DT_i to the k-th cellular UE and to DR_d are denoted as $p_{i,k}$ and $g_{i,d}$, respectively. All channel gains are modeled as combinations of the

Rayleigh fading channel and free-space propagation path loss, so that each element of the channel gain h_{mn} can be expressed as

$$h_{mn} = \sqrt{(d_{mn})^{-\alpha}} h_0 \tag{3}$$

where d_{mn} is the distance from transmitter m to receiver n; α is the path-loss exponent; and h_0 is a complex Gaussian random variable with mean 0 and variance 1.

Furthermore, the transmission power of the BS and DT_i are denoted as P_{B} and P_{D_i}, respectively. To simplify the analysis, the BS is assumed to allocate power equally to each transmitting antenna[15].

1.2 Problem formulation

In this paper, zero-forcing beamforming is applied to precoding of the cellular UEs. Unlike the traditional zero-forcing beamforming method, a joint precoding method is considered. Since the maximum number of streams that can be supported simultaneously is equal to that of transmitting antennas at the BS, the following theorem should hold.

Theorem 1 If the BS with N_{t} transmitting antennas selects K single-antenna cellular UEs for beamforming, the maximum number of degrees of freedom that can avoid interference from the beamforming signal is $N_{\mathrm{t}} - K$.

Based on Theorem 1, we select D_1 D2D pairs as set B_1 to participate in joint zero-forcing beamforming, where $D_1 \leqslant N_{\mathrm{t}} - K$. So, the precoding vector for the k-th cellular UE should satisfy

$$[\boldsymbol{h}_{\mathrm{B},1}, \cdots, \boldsymbol{h}_{\mathrm{B},(k-1)}, \boldsymbol{h}_{\mathrm{B},(k+1)}, \cdots, \boldsymbol{h}_{\mathrm{B},K}, \boldsymbol{f}_{\mathrm{B},1}, \cdots, \boldsymbol{f}_{\mathrm{B},D_1}]^{\mathrm{H}} \boldsymbol{w}_k = \boldsymbol{0} \tag{4}$$

where $\boldsymbol{w}_k$ also satisfies the following two conditions:

$$\boldsymbol{h}_{\mathrm{B},i}^{\mathrm{H}} \boldsymbol{w}_k = 0 \qquad i \neq k; i, k \in A \tag{5}$$

$$\boldsymbol{f}_{\mathrm{B},j}^{\mathrm{H}} \boldsymbol{w}_k = 0 \qquad k \in A; j \in B_1 \tag{6}$$

If we define $\widetilde{\boldsymbol{H}}_{\mathrm{B},k} \triangleq [\boldsymbol{h}_{\mathrm{B},1}, \cdots, \boldsymbol{h}_{\mathrm{B},(k-1)}, \boldsymbol{h}_{\mathrm{B},(k+1)}, \cdots, \boldsymbol{h}_{\mathrm{B},K}, \boldsymbol{f}_{\mathrm{B},1}, \cdots, \boldsymbol{f}_{\mathrm{B},D_1}]^{\mathrm{H}}$, then each $\boldsymbol{w}_k$ lies in the direction of the projection of its own channel $\boldsymbol{h}_{\mathrm{B},k}$ on the null space of $\widetilde{\boldsymbol{H}}_{\mathrm{B},k}$, and it can be formulated as

$$\boldsymbol{w}_k = \frac{(\ker(\widetilde{\boldsymbol{H}}_{\mathrm{B},k}^{\mathrm{H}}))(\ker(\widetilde{\boldsymbol{H}}_{\mathrm{B},k}^{\mathrm{H}}))^{\mathrm{H}} \boldsymbol{h}_{\mathrm{B},k}}{\| \boldsymbol{h}_{\mathrm{B},k} \|} \tag{7}$$

where $\ker(\cdot)$ is the kernel or null space of a matrix. By the joint zero-forcing beamforming, the interference from the BS to the receivers in set B_1 can be eliminated completely, so all the D2D pairs in set B_1 can be admitted to the cellular network. We denote $B_2 = \{1, 2, \cdots, D_2\}$ as the set of the remaining D2D pairs, where $D_2 = D - D_1$. Let the binary variable $\lambda_l \in \{0, 1\}$ represent the admission control status of the l-th D2D pair in set B_2.

$$\lambda_l = \begin{cases} 1 & \text{The } l\text{-th D2D pair in set } B_2 \text{ is admitted} \\ 0 & \text{Other} \end{cases} \tag{8}$$

So, the received signals at the k-th cellular UE, the receiver DR_d in set B_1, and the receiver DR_l in set B_2 can be expressed as

$$z_k^{\mathrm{UE}} = \sqrt{(P_{\mathrm{B}}/N_{\mathrm{t}})} \boldsymbol{h}_{\mathrm{B},k}^{\mathrm{H}} \boldsymbol{w}_k x_k + \sum_{i=1}^{D_1} \sqrt{P_{D_i}} p_{i,k} y_i + \sum_{j=1}^{D_2} \lambda_j \sqrt{P_{D_j}} p_{j,k} y_j + n_k \tag{9}$$

$$z_d^{B1} = \sqrt{P_{D_d}} g_{d,d} y_d + \sum_{i=1, i \neq d}^{D_1} \sqrt{P_{D_i}} g_{i,d} y_i + \sum_{j=1}^{D_2} \lambda_j \sqrt{P_{D_j}} g_{j,d} y_j + n_d \tag{10}$$

$$z_l^{B2} = \lambda_l \sqrt{P_{D_l}} g_{l,l} y_l + \sum_{j=1, j \neq l}^{D_2} \lambda_j \sqrt{P_{D_j}} g_{j,l} y_j + \sum_{i=1}^{D_1} \sqrt{P_{D_i}} g_{i,l} y_i + \sqrt{(P_{\mathrm{B}}/N_{\mathrm{t}})} \sum_{k=1}^{K} \boldsymbol{f}_{\mathrm{B},l}^{\mathrm{H}} \boldsymbol{w}_k x_k + n_l \tag{11}$$

where n_k, n_d, and n_l represent additive Gaussian white noise with mean 0, corresponding to variance σ_k^2, σ_d^2, and σ_l^2, respectively.

The corresponding signal to interference plus noise ratios (SINR) can be calculated as

$$\gamma_k^{\mathrm{UE}} = \frac{(P_{\mathrm{B}}/N_{\mathrm{t}}) |\boldsymbol{h}_{\mathrm{B},k}^{\mathrm{H}} \boldsymbol{w}_k|^2}{\sum_{i=1}^{D_1} P_{D_i} |p_{i,k}|^2 + \sum_{j=1}^{D_2} \lambda_j P_{D_j} |p_{j,k}|^2 + \sigma_k^2} \tag{12}$$

$$\gamma_d^{B1} = \frac{P_{D_d} |g_{d,d}|^2}{\sum_{i=1, i \neq d}^{D_1} P_{D_i} |g_{i,d}|^2 + \sum_{j=1}^{D_2} \lambda_j P_{D_j} |g_{j,d}|^2 + \sigma_d^2} \tag{13}$$

$$\gamma_l^{B2} = \frac{\lambda_l P_{D_l} |g_{l,l}|^2}{\sum_{j=1, j \neq l}^{D_2} \lambda_j P_{D_j} |g_{j,l}|^2 + \sum_{i=1}^{D_1} P_{D_i} |g_{i,l}|^2 + (P_{\mathrm{B}}/N_{\mathrm{t}}) \sum_{k=1}^{K} |\boldsymbol{f}_{\mathrm{B},l}^{\mathrm{H}} \boldsymbol{w}_k|^2 + \sigma_l^2} \tag{14}$$

The rates of unit bandwidth corresponding to the above SINR are denoted as r_k^{UE}, r_d^{B1}, and r_l^{B2} (bit/(s · Hz)). The optimization problem is to maximize the system sum rate, by choosing D2D pairs in set B_2 that can be admitted to the cellular network. The problem is formulated as

$$\max_{\lambda_l} \left(\sum_{k=1}^{K} r_k^{\mathrm{UE}} + \sum_{d=1}^{D_1} r_d^{B1} + \sum_{l=1}^{D_2} r_l^{B2} \right)$$

$$\text{s.t.} \quad \lambda_l \in \{0, 1\}, \quad l = 1, 2, \cdots, D_2 \tag{15}$$

This optimization problem is an NP-hard integer programming problem. It can be solved using an exhaustive search, but the computational complexity is too high for this approach to be practical. In the following section, a novel D2D admission control algorithm based on the combination of beamforming and interference alignment (BIA) is proposed.

2 Admission Control Algorithm Based on BIA

For convenience, we first define the notion of channel parallelism.

Definition 1 (channel parallelism) Assume that the channel vectors from the BS to the i-th user and the j-th user are $\boldsymbol{h}_{B,k}$ and $\boldsymbol{h}_{B,j}$, respectively. The channel parallelism between these two users is calculated as

$$\eta_{i,j} = \frac{|\boldsymbol{h}_{B,k}^{H}\boldsymbol{h}_{B,j}|}{\|\boldsymbol{h}_{B,k}\| \; \|\boldsymbol{h}_{B,j}\|} \tag{16}$$

It is clear that $\eta_{i,j}$ is limited to the domain $[0,1]$. When $\eta_{i,j}=0$, $|\boldsymbol{h}_{B,k}^{H}\boldsymbol{h}_{B,j}|=0$, the two channels are orthogonal. On the contrary, when $\eta_{i,j}=1$, the two channels are parallel with each other, sharing the same direction[16].

As mentioned above, in the D2D communication underlaying cellular network, when the CSI of K cellular UEs and D_1 D2D pairs are used for joint zero-forcing beamforming, the transmission signals at the BS will have no interference on the receivers of D2D pairs in set B_1. This arrangement avoids interference because the channels from the BS to the D2D pairs in set B_1 all lie in the null space of the precoding matrix of the cellular UEs. If we can completely align the interference channels from the BS to the receivers of D2D pairs in set B_2 with the interference channels from the BS to the receivers of the D2D pairs in set B_1, the precoding transmission signals will exert no interference on the receivers of the D2D pairs in set B_2. Unfortunately, the probability of all interference channels being perfectly parallel is almost zero in a practical system. If the channels from the BS to the receivers of D2D pairs in set B_2 are more parallel to the channels from the BS to the receivers of D2D pairs in set B_1, i. e., the value of $\eta_{i,j}$ approaches 1, less interference will arise. The concept of channel parallelism allows the formulation of a D2D admission control algorithm that combines beamforming and interference alignment.

The D2D pairs in set B_1 will participate in joint precoding, which causes the BS to exert no interference on them. Selecting the D2D pairs that have less interference with the cellular UEs to constitute set B_1 is, therefore, a reasonable way to proceed. For simplicity, we select the D_1 D2D pairs that are the farthest away from the BS, i. e., the D2D pairs which have the largest channel gain norm. Other methods can be used to select D2D pairs to constitute set B_1, but they may require additional information, such as the channel gains from the transmitters of D2D pairs to the cellular UEs, which will increase the network overhead.

The proposed D2D admission control algorithm based on BIA consists of the following steps:

1) Initialize: The number of transmitting antennas N_t, number of cellular UEs K, number of D2D pairs D.

2) Select D_1 ($D_1 \leqslant N_t - K$) D2D pairs that are the farthest away from the BS to constitute set B_1 and perform joint zero-forcing beamforming with K cellular UEs.

3) Compute the sum rate R_L for K cellular UEs and D_1 admitted D2D pairs.

4) Compute the channel parallelism $\eta_{i,j}$ between the D2D pairs in set B_1 and set B_2 (constituting set $D_2 = D - D_1$).

5) Sort $\eta_{i,j}$ in a descending order.

6) Assume that the D2D pair with the maximum parallelism (assumed to be the l-th D2D pair) in set B_2 is associated with the cellular network, and compute the temporary sum rate R_+.

7) If $R_+ > R_L$, the l-th D2D pair is admitted to the cellular network, the admission control status of this D2D pair is set to be $\lambda_l = 1$, and $R_L = R_+$. Go to step 8). Else, set $\lambda_l = 0$, and stop.

8) Pick the next most parallel D2D pair in set B_2, and go to step 6).

3 Simulation Results

In this section, the performance of the proposed D2D admission control algorithm based on BIA is discussed with simulation results. In the simulations, the number of the transmitting antennas at the BS is assumed to be $N_t = 6$. The path-loss factor is $\alpha = 2$, and the cell radius is 100 m. Four cellular UEs are uniformly and independently distributed in a central area with a radius of 80 m, and $D = 30$ D2D pairs randomly distributed in a ring area with a radius from 80 to 100 m. The number of D2D pairs in set B_1 is set to be $D_1 = 2$ to allow more channels for interference alignment. The transmission powers of all D2D transmitters are the same and they are much lower than those of the BS, which is set to be $P_D = P_B/20$. The distance between the transmitter and the receiver in each D2D pair is 5 m. The results of 10 000 Monte Carlo simulations are shown in the following figures.

Fig. 2 shows how the sum rate of the cellular UEs and the admitted D2D pairs varies with the transmission power when using four different admission control algorithms. For comparison, the performances of the association vector search algorithm with the maximum ratio transmission (MRT) method, zero-forcing method 1 (ZF1)[14], and the interference alignment (IA) method are also simulated. The MRT algorithm serves each cellular UE and does not perform interference cancelation for other UEs and D2D pairs. The ZF1 algorithm serves each cellular UE and considers interference cancelation among the cellular UEs. The IA algorithm is like the ZF1 algorithm, but the D2D pairs selected for admission are those whose interference channels almost lie within the null space of the precoding matrix of the cellular UEs. In these results, when the transmission power increases, the sum rates of the four algorithms all increase. The proposed algorithm eliminates interference among the cellular UEs, and additionally reduces the interference between the BS and the admitted D2D pairs. This feature explains how the performance of the proposed BIA algorithm is much better than that of the other three algorithms.

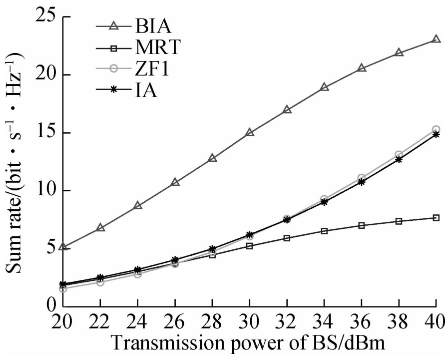

Fig. 2 Sum rate of cellular UEs and admitted D2D pairs

Fig. 3 illustrates the relationship between the sum rate of all the cellular UEs and the transmission power. The D2D admission control affects the sum rate. Our proposed BIA algorithm admits more D2D pairs to the cellular network. But more admitted D2D pairs causes more interference with the cellular UEs. Therefore, the sum rate of all cellular UEs for the proposed algorithm is smaller than that of the other three algorithms. The ZF1 and IA algorithms cancel the interference among the cellular UEs, and the number of the admitted D2D pairs is relatively small, so the sum rates increase rapidly.

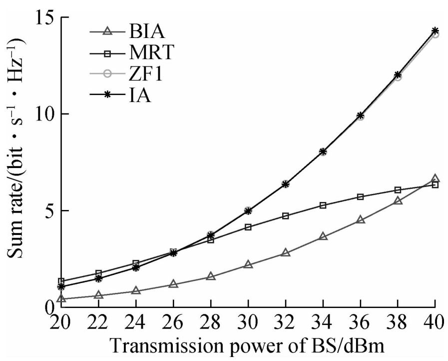

Fig. 3 Sum rate of all cellular UEs

Fig. 4 plots the number of admitted D2D pairs of different algorithms. The MRT and ZF1 algorithms admit no more than 4 D2D pairs. The IA algorithm admits more D2D pairs than the MRT and ZF1 algorithms when the transmission power of the BS is low, but fewer pairs are admitted as the BS transmission power increases. Although the number of admitted D2D pairs for the proposed BIA algorithm gradually decreases as the transmission power increases, it is still much greater than that of the other three algorithms, which explains the superior sum rate performance shown in Fig. 2.

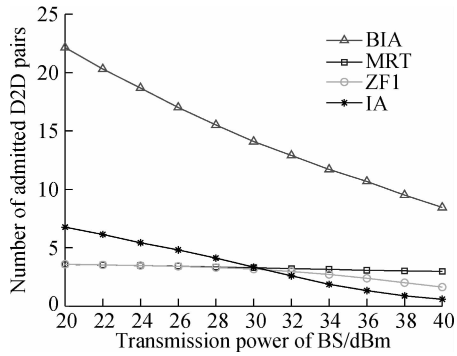

Fig. 4 Number of admitted D2D pairs

Fig. 5 plots the sum rate of all admitted D2D pairs against the transmission power. Since the interference between the BS and the admitted D2D pairs is serious, as the transmission power increases, the sum rates of the other three algorithms stay roughly constant. For our proposed BIA algorithm, the interference between the BS and the D2D pairs in set B_1 is completely eliminated by joint zero-forcing beamforming, and the interference between the BS and the D2D pairs in set B_2 is alleviated by interference alignment. Therefore, as the transmission power increases, the sum rate of all admitted D2D pairs for the proposed algorithm increases.

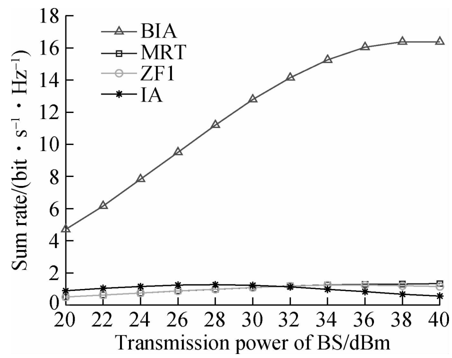

Fig. 5 Sum rate of all admitted D2D pairs

Fig. 6 plots how the system sum rate varies with the distance between the transmitter and the receiver of each D2D pair. The distance varies from 1 to 10 m. The transmission power of the BS is set to be 30 dBm for these simulations, and the transmission power of D2D transmitter is still $P_D = P_B/20$. The system sum rate decreases as the distance between the transmitter and the receiver of D2D pair increases with any of the admission control algorithms. When the distance between the D2D transmitter and the receiver increases, the path loss of the D2D receiver increases, so the sum rate decreases. Therefore, D2D communication performs best at a short range. Furthermore, the proposed algorithm offers significantly better performance than the other three algorithms, even if the D2D devices are somewhat far apart.

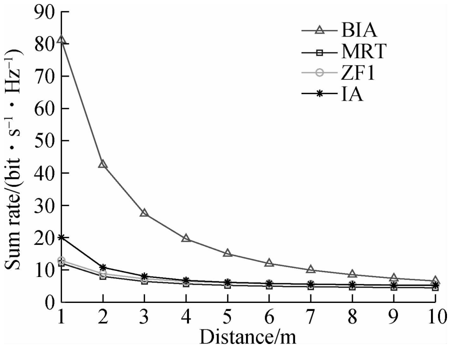

Fig. 6 Sum rate of all cellular UEs and the admitted D2D pairs vs. the distance of D2D pair

4 Conclusion

A D2D admission control algorithm based on BIA that maximizes the system sum rate is proposed. By using the CSI of the cellular UEs and the selection of D2D pairs, we first perform joint zero-forcing beamforming on the cellular UEs, so that the transmitted signals of the BS exert no interference on the selected D2D pairs. For the rest of the D2D pairs, the channel parallelism is computed for the channels from the BS to each pair. Then, in the descending order of channel parallelism, each of the remaining D2D pairs is checked for admission to the network. The algorithm stops when the sum rate of the cellular UEs and admitted D2D pairs decreases. Simulation results show that the proposed BIA algorithm admits more D2D pairs than comparable algorithms and improves system performance significantly.

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基于波束成形和干扰对齐的D2D通信蜂窝网络接入控制

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摘要:提出了一种基于波束成形和干扰对齐的D2D通信蜂窝网络接入控制算法.首先,选择部分距离基站最远的D2D对与蜂窝用户进行联合迫零波束成形并接入网络.基站发射信号对蜂窝用户的干扰和该部分D2D对的干扰被同时完全消除.然后,基于干扰对齐的思想,给出信道平行度的定义.利用基站到D2D设备的信道状态信息,计算未参与联合迫零波束成形的剩余D2D对的信道平行度.信道平行度的值越高,则D2D对受到基站干扰越小.最后,按照信道平行度的降序,逐个检查剩余D2D对是否可以接入蜂窝网络.算法在D2D对的接入使得系统的和速率下降时终止.仿真结果表明,所提算法有效降低了基站发射信号对于D2D用户的干扰,使得系统的容量性能得到显著提高,D2D通信更适用于短距离通信场景.

关键词:D2D通信;蜂窝网络;接入控制;波束成形;干扰对齐

中图分类号:TP915